THE AQUATIC PLANT COMMUNITY OF GOOSE LAKE, ADAMS COUNTY, WISCONSIN

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THE AQUATIC PLANT COMMUNITY FORGOOSE LAKE
ADAMS COUNTY 2006

I. INTRODUCTION

An aquatic macrophyte (plant) field study in Goose Lake was conducted during July 2006 by a staff member from the Wisconsin Department of Natural Resources and a staff member of the Adams County Land and Water Conservatism Department.

Information about the diversity, density and distribution of aquatic plants is an essential component in understanding the lake ecosystem due to the integral ecological role of aquatic vegetation in the lake and the ability of vegetation to impact water quality (Dennison et al, 1993). This study will provide information useful for effective management of Goose Lake, including fish habitat improvement, protection of sensitive areas, aquatic plant management, and water resource regulation. This baseline data will provide information that can be used for comparison to future information and offer insight into changes in the lake.

Ecological Role: Lake plant life is the beginning of the lake's food chain, the foundation for all other lake life. Aquatic plants and algae provide food and oxygen for fish and wildlife, as well as cover and food for the invertebrates that many aquatic organisms depend on. Plants provide habitat and protective cover for aquatic animals. They also improve water quality, protect shorelines and lake bottoms, add to the aesthetic quality of the lake, and impact recreation.

Characterization of Water Quality: Aquatic plants can serve as indicators of water quality because of their sensitivity to water quality parameters such as clarity and nutrient levels (Dennison et al, 1993).

Goose Lake readings for hardness range from 73 to 101 mg of Calcium Carbonate per liter. These readings score the lake's water as "moderately hard". Readings for pH between 2004 and 2006 range from a low of 5.51 to a high of 8.63. Such lakes tend to produce more fish and aquatic plants than soft water lakes.

Background and History: Goose Lake is located in the Town of Jackson, Adams County, Wisconsin. The seepage lake is usually 81 surface acres in size. Maximum depth is 18', with an average depth of 7'. During the summer of 2006 when this aquatic plant survey was conducted, the lake was at an usually low level due to drought and very hot weather.

There is a public boat ramp located on the southeast side of the lake with a small swimming beach immediately north of the ramp. The boat ramp is owned by the Town of Jackson.

Goose Lake is easily accessible off of County Road A. Residential development around the lake is most concentrated along the east and south lakeshores. The surface watershed is 23.7% residential, 17.7% non-irrigated agriculture, 39.8% woodlands and 11.8% water. The ground watershed contains 9.43% irrigated agriculture, 36.69% non-irrigated agriculture, 35.22% woodlands, 11.53% residential, 6.5% water. Capitate spikerush *(Eleocharis flavenscens)* and Robbin's spikerush (*Eleocharis robbinsii)*, both emergents of special concern, is

known to be around the lake. Waterfowl, especially ducks and geese, use this lake during spring and fall.

Fish inventories dating back to 1961 show that largemouth bass and panfish are abundant to common, depending on the species. Northern pike tend to be scarce. Stocking from 1937 to 1953 included bullheads, bluegills, large-mouth bass, crappie, and perch. Similar stocking also occurred in the 1970s.

Soils directly around Goose Lake tend to be sands or loamy sands. Such soils tend to be well-drained or excessively-drained, with infiltration of water being rapid to very rapid, and permeability also high. Such soils also usually have a low water-holding and low organic matter content, thus making them difficult to establish vegetation on. These soils tend to be easily eroded by both water and wind.

Two sensitive areas were designated in Goose Lake in 2001 by Wisconsin Department of Natural Resources staff, with a report issued in 2002. Based partly on the results of the aquatic plant survey in 2006, the sensitive area report will likely be revised to include a third sensitive area (see map in Appendix).

From 1968 through 2004, various chemicals were used for aquatic plant control on Goose Lake. They are outlined in the chart on the next page.

	Aquathol-K	2,4-D	Reward	NuFarm	Cutrine +	K-Tea	CuSO4	Diquat
1968				Weedar 64			230 lbs	
1972	300 lbs						200 lbs	
1977	20 gal	22 gal			4 gal			4 gal
1978	28 gal	4.5 lbs			13.5 gal			6 gal
1979	38 gal				17 gal			
1981	30 gal				15 gal			
1982							50 lbs	16 gal
1983	35 gal				10 gal			
1984	35 gal							
1986	35 gal							
1987	600 lbs							
1996	4.5 gal	10 lbs	4.5 gal		4.5 gal			
1997	30 gal	22.5 lbs	12 gal				60 lbs	
1998	4 gal	13.625 lbs						
1999	24 gal		1 gal			15 gal		
2000	37.5 gal				35 gal			
2001	5 gal	1.75 lbs	3 lbs					
2004				74 gal				
total	**326 gal**	**22 gal**	**17.5 gal**	**74 gal**	**99 gal**	**15 gal**	**540 lbs**	**26 gal**
	900 lbs	**52.375 lbs**	**3 lbs**					

The Goose Lake Improvement Association started having mechanical harvesting of aquatic plants done in 2002 and have continued through 2006. 2006 figures are not yet available.

Year	Lbs Removed
2001	92,000
2002	243,800
2003	242,000
2004	90,000
2005	19,500
total	687,300

II. METHODS

Field Methods

The study was based on the rake-sampling method developed by Jessen and Lound (1962), using stratified random transects. The shoreline was divided into 12 equal sections, with one transect placed randomly within each segment, perpendicular to the shoreline.

One sampling site was randomly chosen in each depth zone (0-1.5'; 1.5'-5'; 5'-10'; 10'-20') along each transect. Using long-handled, steel thatching rakes, four rake samples were taken at each site. Samples were taken from each quarter around the boat. Aquatic species present on each rake were recorded and given a density rating of 0-5.

A rating of 1 indicates the species was present on 1 rake sample.
A rating of 2 indicates the species was present on 2 rake samples.
A rating of 3 indicates the species was present on 3 rake samples.
A rating of 4 indicates the species was present on 4 rake samples.
A rating of 5 indicates that the species was abundantly present on all rake samples.

A visual inspection and periodic samples were taken between transects to record the presence of any species that didn't occur at the raking sites. Gleason and Cronquist (1991) nomenclature was used in recording plants found.

Shoreline type was also recorded at each transect intercept. Visual inspection was made of 50' to the right and left of the boat along the shoreline, 35' back from the

shore (so total view was 100' x 35'). Percent of land use within this rectangle was visually estimated and recorded.

Data Analysis:

The percent frequency (number of sampling sites at which it occurred/total number of sampling sites) of each species was calculated. (See Appendix A) Relative frequency (number of species occurrences/total all species occurrences) was also determined. (See Appendix A) The mean density (sum of species' density rating/number of sampling sites) was calculated for each species. (See Appendix B) Relative density (sum of species' density/total plant density) was also determined. (See Appendix B) Mean density where present (sum of species' density rating/number of sampling sites at which the species occurred) was calculated. (See Appendix B) Relative frequency and relative density results were summed to obtain a dominance value. (See Appendix C) Species diversity was measured by Simpson's Diversity Index. (See Appendix A)

The Average Coefficient of Conservatism and Floristic Quality Index were calculated as outlined by Nichols (1998) to measure plant community disturbance. A coefficient of Conservatism is an assigned value between 0 and 10 that measures the probability that the species will occur in an undisturbed habitat. The Average Coefficient of Conservatism is the mean of the coefficients for the species found in the lake. The coefficient of conservatism is used to calculate the Floristic Quality Index, a measure of a plant community's closeness to an undisturbed condition.

An Aquatic Macrophyte Index was determined using the method developed by Nichols et al (2000). This measurement looks at the following seven parameters that characterize a plant community and assigns each of them a number on a scale of 1-10: maximum depth of plant growth; percentage of littoral zone vegetated; Simpson's diversity index; relative frequency of submersed species; relative frequency of sensitive species; taxa number; and relative frequency of exotic species. The average total for the North Central Hardwoods lakes and impoundments is between 48 and 57.

III. RESULTS

Physical Data

The aquatic plant community can be impacted by several physical parameters. Water quality, including nutrients, algae and clarity, influence the plant community; the plant community in turn can modify these boundaries. Lake morphology, sediment composition and shoreline use also affect the plant community.

The trophic state of a lake is a classification of water quality (see Table 1). Phosphorus concentration, chlorophyll a concentration and water clarity data are collected and combined to determine a trophic state. **Eutrophic lakes** are very productive, with high nutrient levels and large biomass presence. **Oligotrophic lakes** are those low in nutrients with limited plant growth and small fisheries. **Mesotrophic lakes** are those in between, i.e., those which have increased production over oligotrophic lakes, but less than eutrophic lakes; those with more biomass than oligotrophic lakes, but less than eutrophic lakes; those with a good and more varied fishery than either the eutrophic or oligotrophic lakes.

The limiting factor in most Wisconsin lakes, including Goose Lake, is phosphorus. Measuring the phosphorus in a lake system thus provides an indication of the nutrient level in a lake. Increased phosphorus in a lake will feed algal blooms and also may cause excess plant growth. **The 2004-2006 summer average phosphorus concentration in Goose Lake was 16 ug/l.** This is below the 25 ug/l average for natural lakes. This concentration suggests that Goose Lake is likely to have some nuisance algal blooms, but not frequent ones. This places Goose Lake in the "good" water quality section for natural lakes and in the mesotrophic level for phosphorus.

Chlorophyll concentrations provide a measure of the concentration of algae in a lake's water. Algae are natural and essential in lakes, but high algal populations can increase water turbidity and reduce light available for plant growth. **The 2004-2006 summer average chlorophyll concentration in Goose Lake was 3.23 ug/l.** This is very low, placing Goose Lake at the oligotrophic level for chlorophyll a results.

Water clarity is a critical factor for plants. If plants receive less than 2% of the surface illumination, they won't survive. Water clarity can be reduced by turbidity (suspended materials such as algae and silt) and dissolved organic chemicals that color or cloud the water. Water clarity is measured with a Secchi disk. **Average summer Secchi disk clarity in Goose Lake in 2004-2006 was 6.85'.** This is good clarity, putting Goose Lake into the mesotrophic category for water clarity.

It is normal for all of these values to fluctuate during a growing season. They can be affected by human use of the lake, by summer temperature variations, by algae growth & turbidity, and by rain or wind events. Phosphorus tends to rise in early summer, than decline as late summer and fall progress. Chlorophyll a tends to rise in level as the water warms, then decline as autumn cools the water. Water clarity also tends to decrease as summer progresses, probably due to algae growth, then increase as fall approaches.

Table 1: Trophic States

Trophic State	Quality Index	Phosphorus (ug/l)	Chlorophyll a (ug/l)	Sechhi Disk (ft)
Oligotrophic	Excellent	<1	<1	>19
	Very Good	1 to 10	**1 to 5**	8 to 19
Mesotrophic	Good	**10 to 30**	5 to 10	**6 to 8**
	Fair	30 to 50	10 to 15	5 to 6
Eutrophic	Poor	50 to 150	15 to 30	3 to 4
Goose Lake		**16**	**3.23**	**6.85**

According to these results, Goose Lake scores as **"mesotrophic"** in its phosphorus and Secchi disk levels and "**oligotrophic"** in chlorophyll a readings. This state would favor moderate plant growth, occasional algal blooms and good water clarity.

Lake morphology is an important factor in distribution of lake plants. Duarte & Kalff (1986) determined that the slope of a littoral zone could explain 72% of the observed variability in the growth of submerged plants. Gentle slopes support higher plant growth than steep slopes (Engel 1985).

Goose Lake is a shallow, irregularly-shaped, widely-lobed lake with abundant wetlands on its northern shore. The littoral zone tends to slope gradually. There are a couple of areas of steeper slopes within the lake where the littoral zone drops off in the lobe near the boat ramp. With good water clarity, plant growth may be favored in more of Goose Lake than one might expect since the sun can get to a most of the sediment to stimulate plant growth.

Sediment composition can also affect plant growth, especially rooted vegetation. The richness or sterility and texture of the sediment will determine the type and abundance of macrophyte species that can survive in a particular lake (see Table 2 and Appendix A).

Table 2: Sediment Composition—Goose Lake

Sediment	**Type**	**0-1.5'**	**1.5'-5'**	**5'-10'**	**10'-20'**	**All Sites**
Hard	Sand	26.67%	11.76%			13.95%
Mixed	Sand/Marl	6.67%				2.33%
	Sand/Silt	20%				6.98%
Soft	Silt/Marl		5.58%	80%	100%	2.33%
	Silt/Muck		5.58%			2.33%
	Silt/Peat		17.65%			6.98%
	Peat	33.33%	53.85%			53.47%
	Silt	13.33%	5.58%	20%		11.63%

Over 75% of the sediment in Goose Lake is soft with natural fertility and significant available water holding capacity. Although sand sediment may limit growth, all sandy sites in Goose Lake were vegetated. In fact, all sample sites were vegetated in Goose Lake, regardless of the sediment (see Appendix G).

Shoreline land use often strongly impacts the aquatic plant community and thus the entire aquatic community. Impacts can be caused by increased erosion and sedimentation and higher run-off of nutrients, fertilizers and toxins applied to the land. Such impacts occur in both rural and residential settings.

Native herbaceous vegetation was the shoreline cover with the highest mean coverage (see Table 3). But disturbed sites, such as those with traditional lawn, rock/riprap, hard structures and pavement, were also common, covering nearly 20% of the shoreline (19.71%). Bare unprotected soil was found (4.71%).

Table 3: Shoreland Land Use—Goose Lake

Cover Type		Occurrence frequency at transects	Percent Coverage
Vegetated	Wooded	35.29%	12.35%
Shoreline	Herbaceous	88.24%	42.94%
	Shrubs	64.71%	20.29%
Disturbed	Cultivated Lawn	29.41%	12.65%
Shoreline	Hard Structures	35.29%	3.53%
	Rock/riprap/pavement	17.64%	5.82%
	Bare Sand	35.28%	4.71%

Some type of natural shoreline was found at 88% of the sites and covered 76.23% of the lake shoreline.

Macrophyte Data

SPECIES PRESENT

Of the 42 species found in Goose Lake, 39 were native and 3 were exotic invasives. In the native plant category, 18 were emergent, 4 were floating-leaf

rooted plants, and 20 were submergent types (see Table 4). One macrophytic (plant-like) algae, *Chara* spp. (muskgrass) was also found. One species of special concern, *Eleocharis robbinsii*, was found. Three exotic invasives, *Lythrum salicaria* (Purple Loosestrife) *Myriophyllum spicatum* (Eurasian Water Milfoil), and *Phalaris arundinacea* (reed canary grass) were found.

Table 4—Plants Found in Goose Lake, 2006

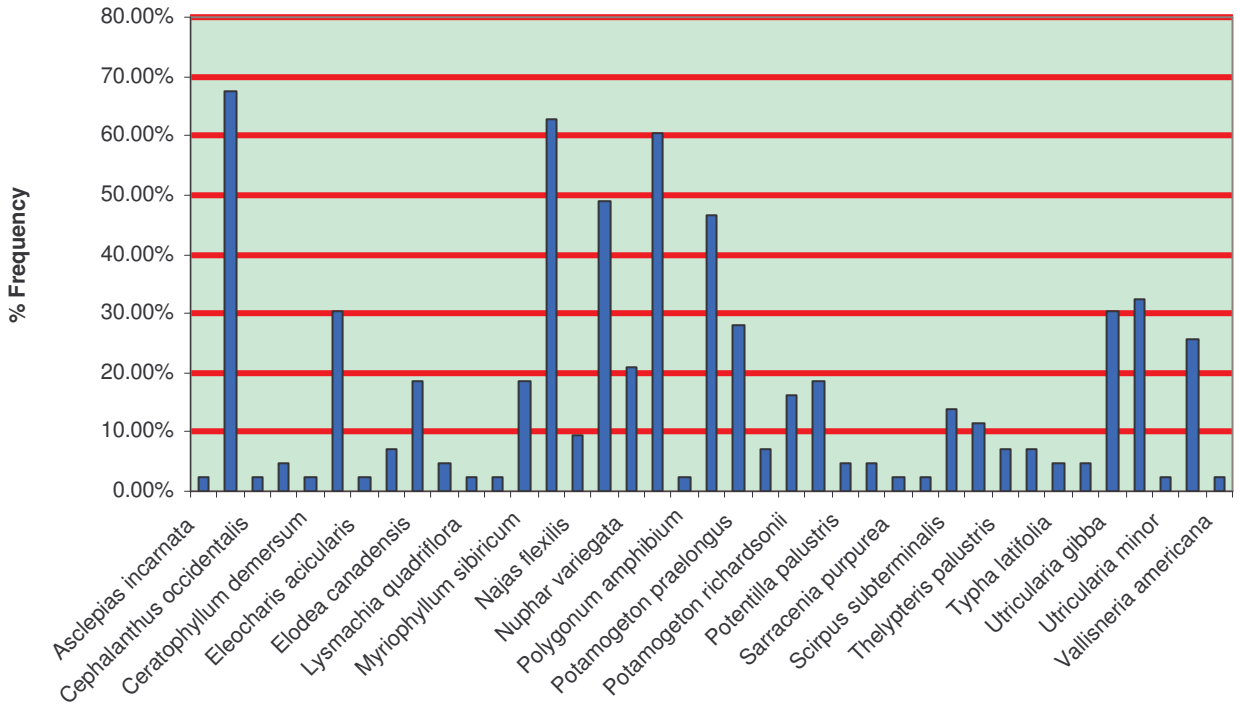
Scientific Name	Common Name	Plant Type
Asclepias incarnata	Swamp Milkweed	Emergent
Brasenia schreberi	Watershield	Floating-Leaf
Cephalanthus occidentalis	Common Buttonbush	Emergent
Carex crawfordii	Crawford's Sedge	Emergent
Carex hystericina	Bottlebrush Sedge	Emergent
Ceratophyllum demersum	Coontail	Submergent
Chara spp	Muskgrass	Submergent
Cladium mariscoides	Twig Rush	Emergent
Eleocharis acicularis	Needle Spikerush	Emergent
Eleocharis robbinsii	Robbin's Spikerush	Submergent
Elodea canadensis	Waterweed	Submergent
Juncus pelocarpus	Brownfruit Rush	Submergent
Lysmachia quadriflora	4-Flower Yellow Loosestrife	Emergent
Lythrum salicaria	Purple Loosestrife	Invasive
Myriophyllum sibiricum	Northern Milfoil	Submergent
Myriophyllum spicatum	Eurasian Watermilfoil	Invasive
Najas flexilis	Bushy Pondweed	Submergent
Najas guadelupensis	Southern Naiad	Submergent
Nuphar variegata	Varigated Yellow Pond Lily	Floating-Leaf
Nymphaea odorata	White Water Lily	Floating-Leaf
Phalaris arundinacea	Reed Canarygrass	Invasive
Polygonum amphibium	Water Smartweed	Floating-Leaf
Potamogeton illinoensis	Illinois Pondweed	Submergent
Potamogeton praelongus	White-Stemmed Pondweed	Submergent
Potamogeton pusillus	Small Pondweed	Submergent
Potamogeton richardsonii	Clasping-Leaf Pondweed	Submergent
Potamogeton zosteriformis	Flat-Stemmed Pondweed	Submergent
Potentilla palustris	Marsh Cinquefoil	Emergent
Sagittaria spp	Duck Potato/Arrowhead	Emergent
Sarracenia purpurea	Purple Pitcher Plant	Emergent
Scirpus pungens	Common 3-Square Bulrush	Emergent
Scirpus subterminalis	Water Bulrush	Emergent

Scirpus validus	Soft-Stem Bulrush	Emergent
Thelypteris palustris	Marsh Fern	Emergent
Typha angustifolia	Narrow-Leaf Cattail	Emergent
Typha latifolia	Wide-Leaf Cattail	Emergent
Utricularia gemniscapa	Twin-Stemmed Bladderwort	Submergent
Utricularia gibba	Creeping Bladderwort	Submergent
Utricularia intermedia	Flat-Leaved Bladderwort	Submergent
Utricularia minor	Lesser Bladderwort	Submergent
Utricularia vulgaris	Common Bladderwort	Submergent
Vallisneria americana	Water Celery	Submergent

FREQUENCY OF OCCURRENCE

Brasenia schreberi was the most frequently-occurring "plant" in Goose Lake in 2006 (67.44% frequency), followed closely by *Myriophyllum spicatum* (62.79%) and *Nymphaea odorata* (60.47%). No other species reached a frequency of 50% or greater.

Chart 1: Frequency Occurrence

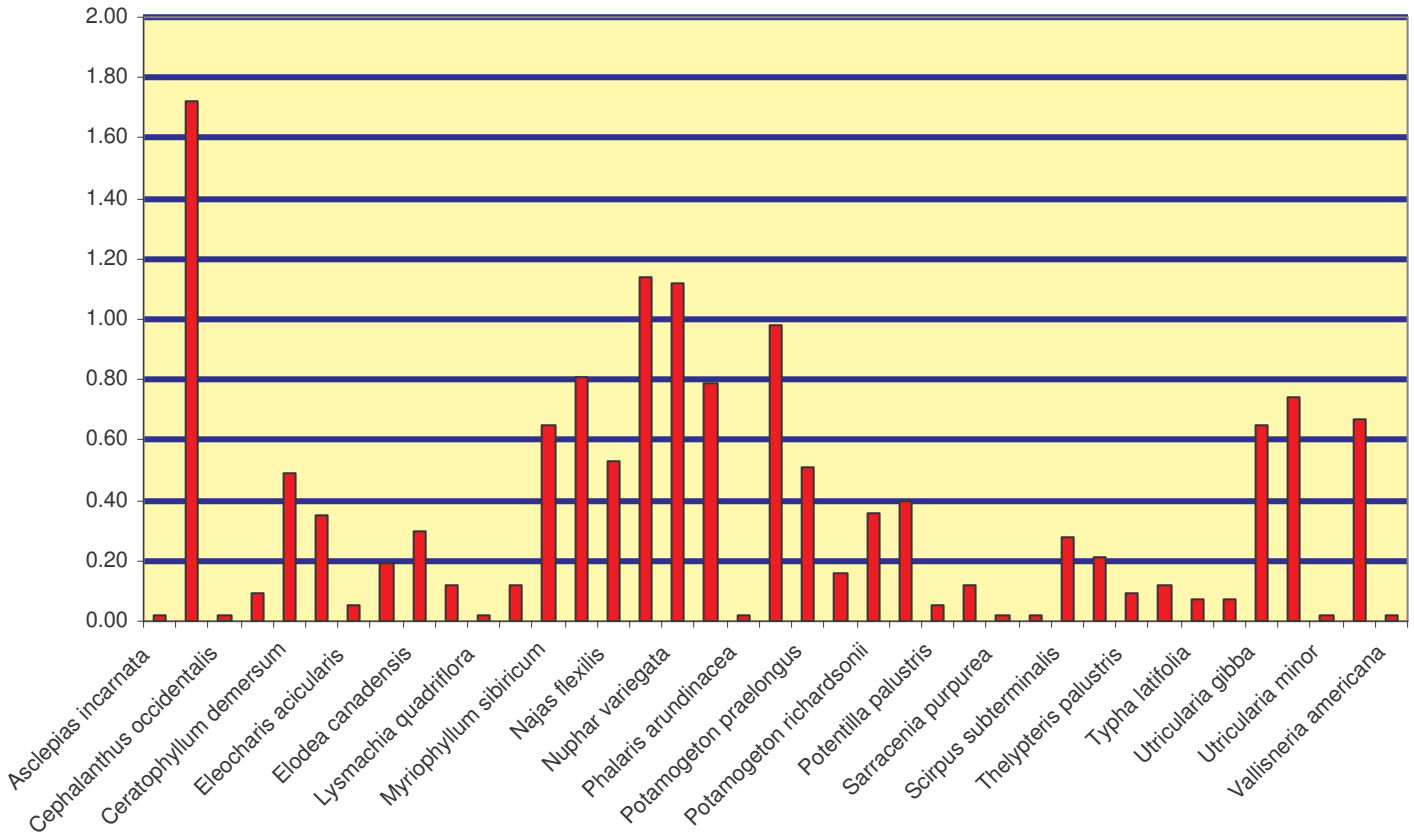


Filamentous algae was found at 41.86% of the sample sites. It occurred at 40% of the sites in the 0-1.5' depth; at 20.41% of the 1.5'-5' dept zone sites; and at 60% of the 5'-10' zone sites. It was also found at the one site over 10' in depth.

DENSITY OF OCCURRENCE

Brasenia schreberi was also the densest plant in Goose Lake, with a mean density of 1.72. *Najas guadelupensis* (1.14) and *Nuphar variegata* (1.12) also had mean densities over 1.0. Since no plant had a mean density over 2.0, none of the aquatic vegetation in Goose Lake occurred at more than average density overall in the lake in summer 2006. *Brasenia schreberi* (2.07) and *Nymphaea odorata* (2.13) occurred at slightly more than average density in Depth Zone 1 (0-1.5'). *Najas guadelupensis* occurred at more than average density in Depth Zone 2 (1.5'-5') and in Depth Zone 3 (5'-10') with densities of 2.35 and 2.7 respectively. *Potamogeton zosteriformis* occurred at a more than average density in Depth Zone 4.

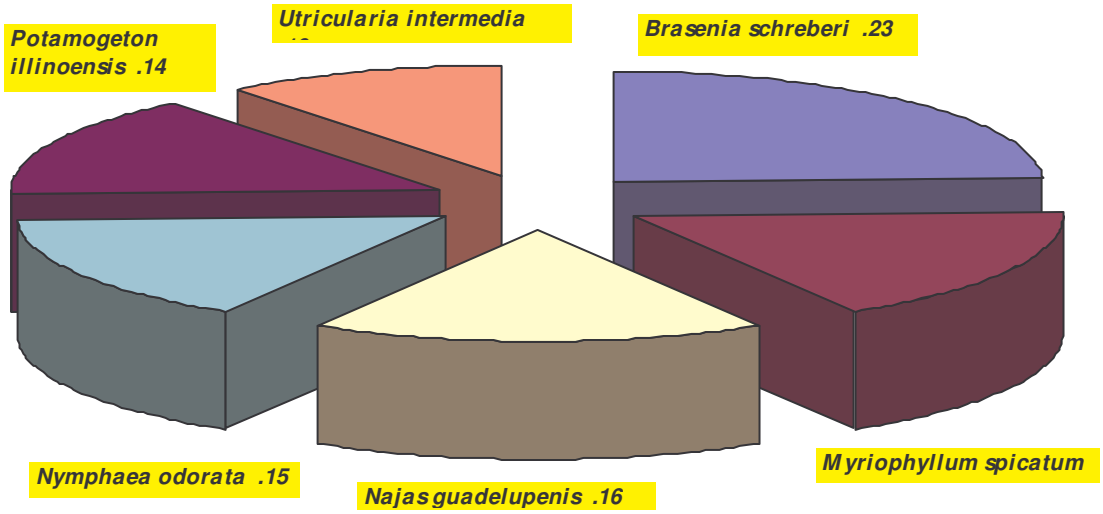
Chart 2: Mean Density of Occurrence



DOMINANCE

Relative frequency and relative density of a species are combined into a dominance value that demonstrates how dominant thagt species is within its aquatic plant community. Based on dominance value, *Brasenia schreberi* was the dominant aquatic plant species in Goose Lake. Sub-dominant species were *Myriophyllum spicatum*, *Najas guadelupensis*, and *Nymphaea odorata. Potamogeton crispus* and *Phalaris arundinacea*, the other two exotics found Goose Lake, were not present in high frequency, high density or high dominance.

Chart 3: Dominance Value .10 or Over



Brasenia schreberi and *Nymphaea odorata* were dominant in Depth Zones 1 and 2. *Najas guadelupensis* and *Myriophyllum spicatum* were dominant in Depth Zone 3. *Myriophyllum spicatum* was subdominant in Depth Zones 1 and 2. In Depth Zone 4, the dominant plant was *Potamogeton zosteriformis.*

DISTRIBUTION

Aquatic plants occurred at 100% of the sample sites in Goose Lake to a maximum rooting depth of 11'. Rooted-floating-leaf plants were found in the three shallowest zones (see Appendix B). Submergent plants were found over the entire lake, while emergent plants were found in Depth Zone 1 at 58.82% of the sample sites (see maps in Appendix)

Chart 4: Macrophyte Frequency

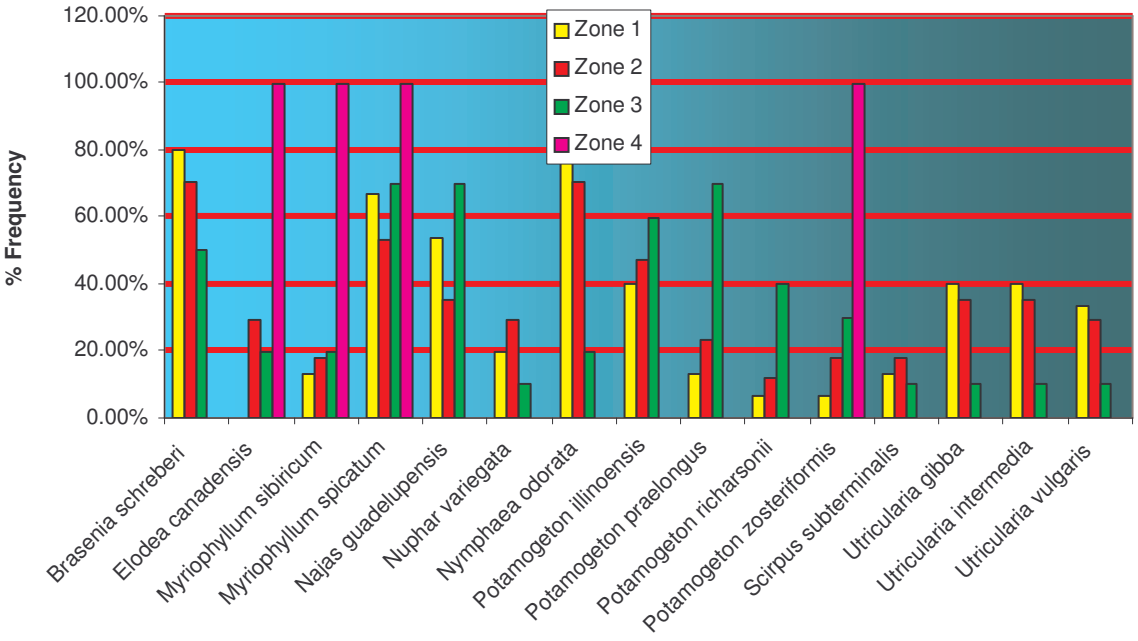
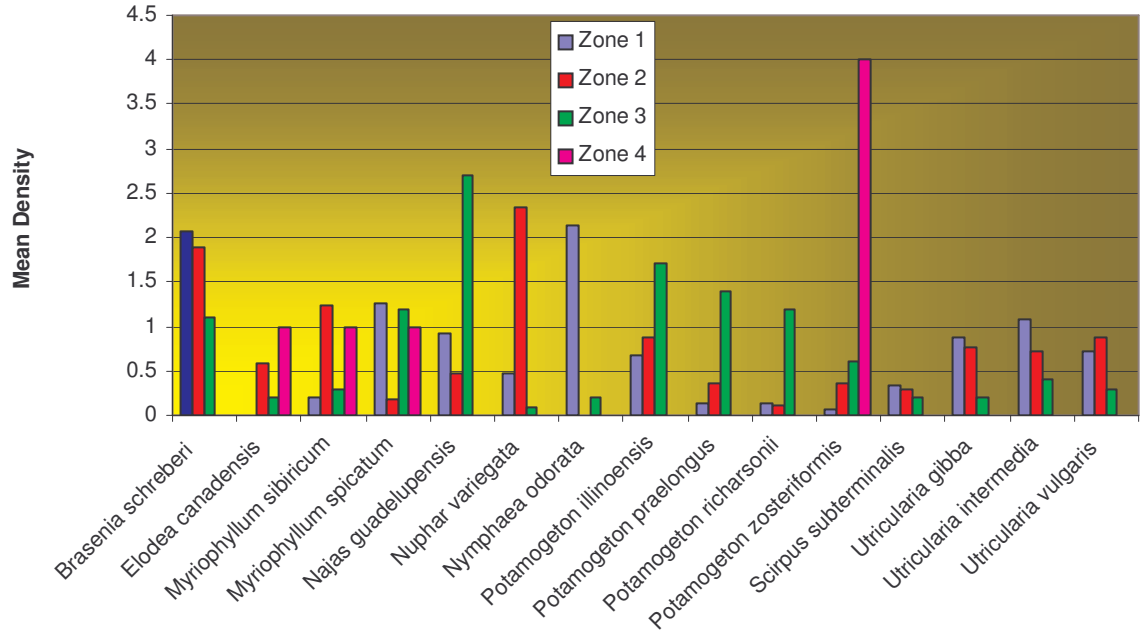


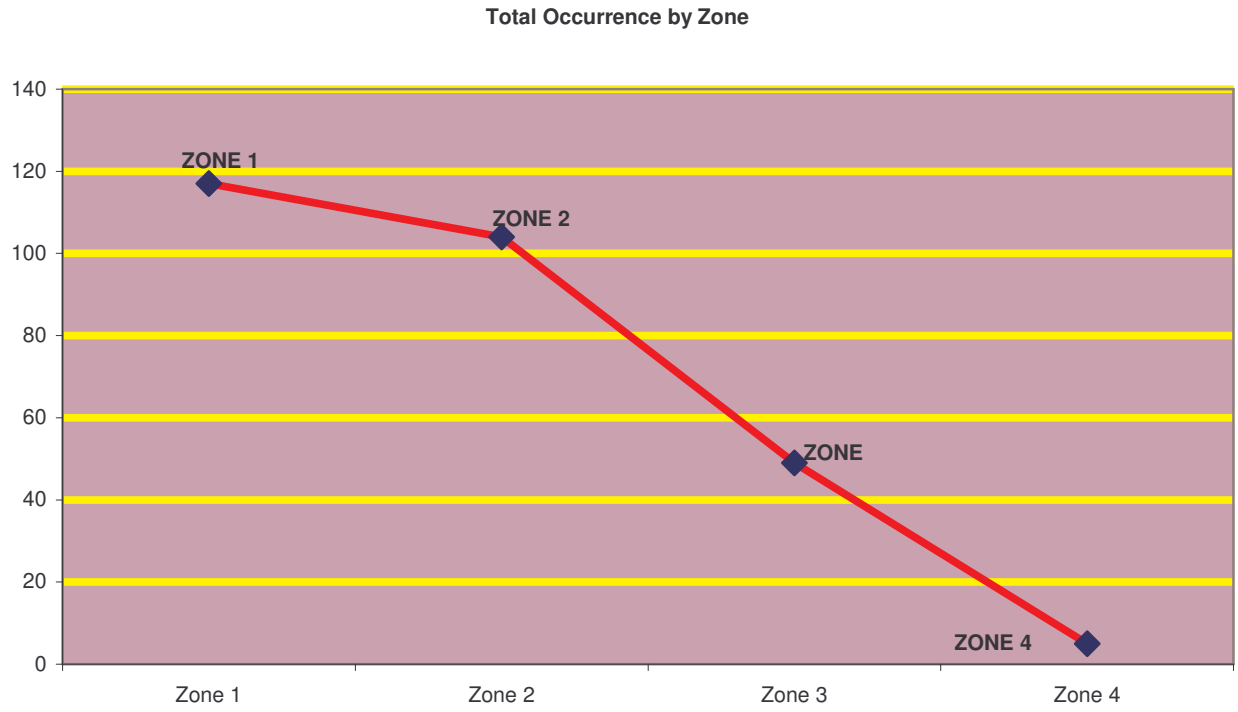
Chart 5: Macrophyte Density

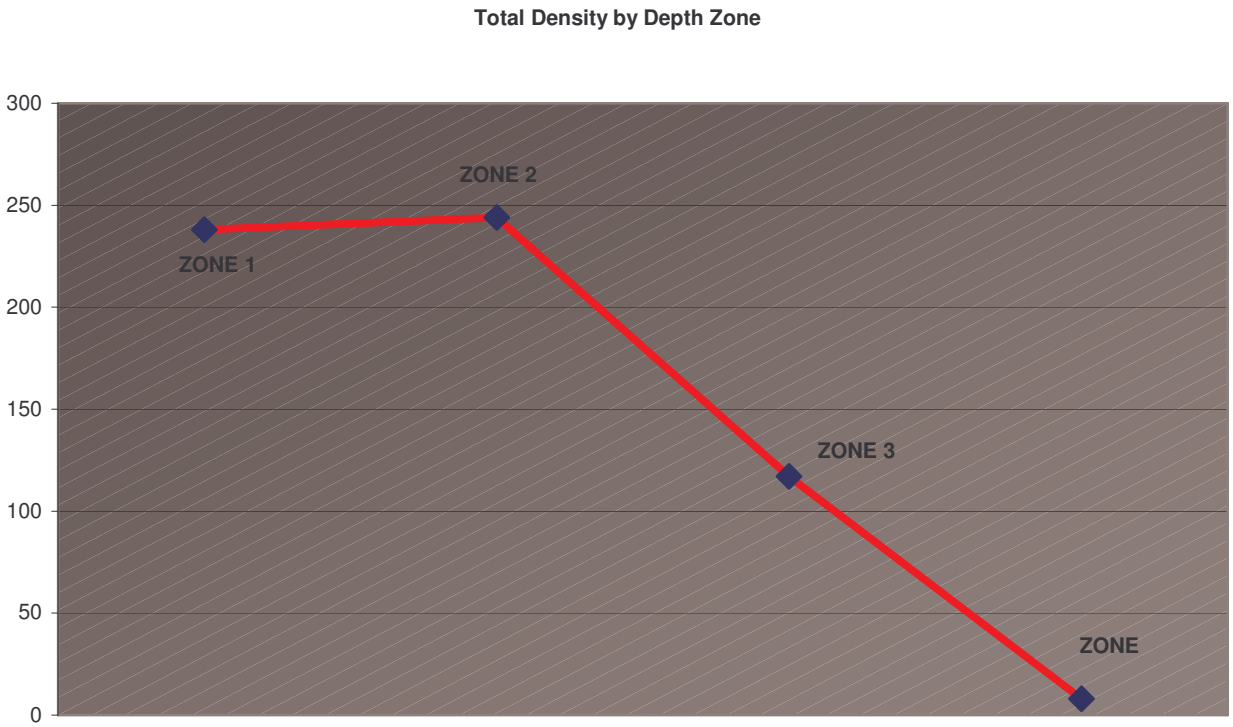


Secchi disc readings are used to predict maximum rooting depth for plants in a lake (Dunst, 1982). Based on the summer 2004-2006 Secchi disc readings, the

predicted maximum rooting depth in Goose Lake would be **11.09 feet.** During the 2006 aquatic plant survey, rooted plants were found at a depth of **11'**, i.e., rooted plants were found deeper than would usually be expected by Dunst calculations.

The 0-1.5' depth zone (Zone 1) produced the greatest occurrence of plant growth, followed closely by Zone 2 (1.5'-5'). Zone 2 had the highest total density of plants, followed closely by Zone 1. Both occurrence and density dropped off sharply at depths over 5', although plants were still found in those depths.





The greatest number of species per site (species richness) was found in Zone 1, with a 7.8 richness score. Zone 3 had the lowest species richness (4.9), followed

closely by Zone 4 (5.0). Zone 3 had a species richness of 6.18. Overall species richness was 6.4.

THE COMMUNITY

The Simpson's Diversity Index Goose Lake was .94, suggesting excellent species diversity. A rating of 1.0 would mean that each plant in the lake was a different species (the most diversity achievable). The Aquatic Macrophyte Community Index (AMCI) for Goose Lake is 57. This is in the average range for Central Wisconsin Hardwood Lakes and all Wisconsin lakes.

Table 5: Aquatic Macrophyte Community Index

Aquatic Macrophyte Community Index for Goose Lake		
Category	Goose Lake results	Value
Maximum rooting depth	11'	6
% littoral area vegetated	100%	10
%submersed plants	64%	6
% sensitive plants	38%	10
# taxa found	41 (3 exotic)	10
exotic species frequency	10%	5
Simpon's Diversity	94	10
total		**57**

The presence of several invasive, exotic species is a significant factor. Reed Canarygrass was noted as present in several places, although not found at any of the surveyed sites. Eurasian Watermilfoil was evident all over the lake (see Appendix I). Its tenacity and ability to spread to large areas fairly quickly make it a danger to the diversity of Goose Lake's current excellent aquatic plant community.

A Coefficient of Conservatism and a Floristic Index calculation were performed on the field results. Technically, the average Coefficient of Conservatism measures the community's sensitivity to disturbance, while the Floristic Index measures the community's closeness to an undisturbed condition. Indirectly, they measure past and/or current disturbance to aquatic plant community.

Previously, a value was assigned to all plants known in Wisconsin to categorize their probability of occurring in an undisturbed habitat. This value is called the plant's Coefficient of Conservatism. A score of 0 indicates a native or alien opportunistic invasive plant. Plants with a value of 1 to 3 are widespread native plants. Values of 4 to 6 describe native plants found most commonly in early successional ecosystem. Plants scoring 6 to 8 are native plants found in stable climax conditions. Finally, plants with a value of 9 or 10 are native plants found in areas of high quality and are often endangered or threatened. In other words, the lower the numerical value a plant has, the more likely it is to be found in disturbed areas.

The Average Coefficient of Conservatism Goose Lake was 6.02. This puts it in the average range for Wisconsin Lakes (6.0) and for lakes in the North Central Hardwood Region (5.6). The aquatic plant community in Goose Lake is in the category of those somewhat tolerant of disturbance, probably due to selection by a series of past disturbances.

The Floristic Quality Index of the aquatic plant community in Goose Lake of 38.57 is quite above average for Wisconsin Lakes (22.2) and the North Central Hardwood Region (20.9). This indicates that the plant community in Goose Lake is farther from an undisturbed condition than the average lake in Wisconsin

overall and in the North Central Hardwood Region. In other words, the aquatic plant community in Goose Lake has been not been impacted by an above average amount of disturbance.

"Disturbance" is a term that covers many disruptions to a natural community. It includes physical disturbances to plant beds such as boat traffic, plant harvesting, chemical treatments, dock and other structure placements, shoreline development and fluctuating water levels. Indirect disturbances like sedimentation, erosion, increased algal growth, and other water quality impacts will also negatively affect an aquatic plant community. Biological disturbances such as the introduction of non-native and/or invasive species (such as the Eurasian Watermilfoil, Reed Canarygrass and Purple Loosestrife found here), destruction of plant beds, or changes in aquatic wildlife can also negatively impact an aquatic plant community. Shore development and sediment deposition can also reduce the quality of the aquatic plant community. Shoreline development, introduction of non-native plant species and boat traffic are likely the major disturbances in Goose Lake.

Many of the sample transects had an entirely native shore, a comparison was made between the aquatic plant communities of the shore disturbed by humans and those not yet disturbed.

	Natural	Disturbed
Number of species	35	27
FQI	35.67	30.79
Average Coef. Of Cons	6.03	5.93
Simpson's Index	0.94	0.93
Filamentous algae	39%	45%

Using these figures, the natural, undisturbed shores had higher readings for Number of Species, Floristic Quality Index, Average Coefficient of Conservatism and Simpson's Index of Diversity. The natural shores also had less filamentous algae.

IV. DISCUSSION

Based on water clarity, chlorophyll and phosphorus data, Goose Lake is an oligotrophic to mesotrophic seepage lake with good to very good water clarity and good water quality. This trophic state should support moderate plant growth and occasional algal blooms.

Sufficient nutrients (trophic state), hard water, good water clarity, shallow lake, and soft sediments at Goose Lake favor plant growth. Despite the sometime limiting effect of sand sediments on aquatic plant growth, 100% of the lake is vegetated, suggesting that even the sand sediments in Goose Lake hold sufficient nutrients to maintain aquatic plant growth.

Continuing machine harvesting and spot-treating the exotics should help in removing vegetation (and phosphorus) from the lake and may somewhat help with nutrient reduction. The harvesting should also be designed to set back the growth of Eurasian Watermilfoil, not spread it further. Current harvesting does not appear to be targeting EWM.

The lake does have a good mixture of emergent, floating and rooted plants. Of the 42 species recorded in Goose Lake in summer 2006, 18 were emergent, 4 were floating-leaf and 20 were submergent. Three invasive exotics were found during

the 2007 field survey: Eurasian watermilfoil; Purple Loosestrife; and Reed Canarygrass. In particular, Eurasian watermilfoil was found throughout the lake making it easy for boat propellers and lake traffic to fragment it and cause further spread. The other two exotic species were not found at high frequencies or densities.

The most developed shore—that along the northeast side of the lake—has many "grandfathered" buildings that are close to the shore, suggesting that runoff from impervious surfaces such as decks or rooftops could be adding to the pollutant load in the lake. Installation of as much buffer (native) vegetation as possible between the buildings and the ordinary high water mark could filter pollutants and nutrients and help keep them out of the lake water.

Along the south and west shores, there are areas of wooded and wetland shores that should be preserved as it is to maintain habitat and to serve as a buffer for that area. Studies have suggested that runoff from establish wooded land is substantially less than that of developed areas.

The summer 2006 field survey showed that *Myriophyllum spicatum* (Eurasian Watermilfoil) is on its way to dominating the aquatic plant community of Goose Lake unless it is further checked. It already occurs at nearly 63% frequency of the aquatic plant community. At this point, at least, it is not at higher than average densities. But its tenacity and ability to spread to large areas fairly quickly make it a danger to the diversity of Goose Lake's excellent aquatic plant community. Targeting this plant by specific plant management techniques may help keep its spread in check.

The Simpson's Diversity Index for Goose Lake was .94, suggesting excellent species diversity. The Aquatic Macrophyte Community Index (AMCI) Goose Lake is 57 (see Table 6) for Central Wisconsin Hardwood Lakes. The 6.02 Average Coefficient of Conservatism score puts Goose Lake is in the category of those somewhat tolerant of disturbance. However, the Floristic Quality Index of the aquatic plant community in Goose Lake of 38.57 is above average for Wisconsin Lakes and lakes in the North Central Hardwood Region. This indicates that the plant community in Goose Lake closer to an undisturbed condition than the average state or regional lake.

Some kind of native vegetation was the dominant shore cover in Goose Lake (total of 75.63%). However, disturbed sites, such as those with cultivated lawn, hard structure, rock/riprap and pavement, were also common, with coverage of nearly 25%. Of natural shorelines, herbaceous cover was most frequently found (88%), with coverage of nearly 43%. Some type of disturbed shoreline was found at over 47% of the sites. These conditions offer little protection for water quality and have significant potential to negatively impact Goose Lake's water by increased runoff (including lawn fertilizers, pet waste, pesticides) and shore erosion. Expanding the amount of native vegetation at these shorelines would help prevent erosion and reduce runoff into the lake that contributes to algal growth, increased sedimentation, nutrient enrichment, and reduced water quality.

V. CONCLUSIONS

Goose Lake is an oligotrophic to mesotrophic lake with good to very good water quality and water clarity. The quality of the aquatic plant community in Goose Lake is above average for Wisconsin lakes and for lakes in the North Central Hardwood region, as measured by Floristic Quality Index and about average as measured by the AMCI. Filamentous algae is common. Structurally, it contains emergent plants, rooted plants with floating leaves, and submergents. Further, it contains several sensitive high quality aquatic plants and one of special concern. Protection of this special high-quality aquatic plant community is essential.

When the aquatic plant survey was performed, 100% of the littoral zone was vegetated. The potential for plant growth at all depths of the lake is present, even though some of the lake sediments are sandy and less favorable for growth. This percent plant cover is over the recommended vegetation cover for optimum fishery (50%-85%).

Brasenia schreberi was the most frequently-occurring "plant" in Goose Lake in 2006 (67.44% frequency), followed closely by *Myriophyllum spicatum* (62.79%) and *Nymphaea odorata* (60.47%). No other species reached a frequency of 50% or greater.

Brasenia schreberi was also the plant with the highest mean density in Goose Lake, with a mean density of 1.72. *Najas guadelupensis* (1.14) and *Nuphar variegate* (1.12) also had mean densities over 1.0. Since no plant had a mean density over 2.0, none of the aquatic vegetation in Goose Lake occurred at more than average density overall in the lake in summer 2006. *Brasenia schreberi*

(2.07) and *Nymphaea odorata* (2.13) occurred at slightly more than average density in Depth Zone 1 (0-1.5'). *Najas guadelupensis* occurred at more than average density in Depth Zone 2 (1.5'-5') and in Depth Zone 3 (5'-10') with densities of 2.35 and 2.7 respectively. *Potamogeton zosteriformis* occurred at a more than average density in Depth Zone 4.

A healthy and diverse aquatic plant community plays a vital role within the lake ecosystem. Plants help improve water quality by trapping nutrients, debris and pollutants in the water body; by absorbing and/or breaking down some pollutants; by reducing shore erosion by decreasing wave action and stabilizing shorelines and lake bottoms; and by tying-up nutrients that would otherwise be available for algae blooms. Aquatic plants provide valuable habitat resources for fish and wildlife, often being the base for the multi-level food chain in the lake ecosystem, and also produce oxygen needed by animals.

Further, a healthy and diverse aquatic plant community can better resist the invasion of species (native and non-native) that might otherwise "take over" and create a lower quality aquatic plant community. A well-established and diverse plant community of natives can help check the growth of more tolerant (and less desirable) plants that would otherwise crowd out some of the more sensitive species, thus reducing diversity.

Vegetated lake bottoms support larger and more diverse invertebrate populations than non-vegetated lake bottoms. These in turn support larger and more diverse fish and wildlife populations (Engel, 1985). Also, a mixed stand of aquatic macrophytes (plants) supports 3 to 8 times more invertebrates and fish than do

monocultural stands (Engel, 1990). A diverse plant community creates more microhabitats for the preferences of more diverse fish and wildlife communities.

MANAGEMENT RECOMMENDATIONS

(1) Because the plant cover in the littoral zone of Goose Lake is over the ideal (25%-85%) coverage for balanced fishery, consideration should be given to reducing plant growth in at least some areas. A map of areas to have plants removed should be developed, then removal should occur by hand to be sure that entire plants are removed and to minimize the amount of disturbance to the settlement.

(2) Natural shoreline restoration in some areas is needed. Disturbed shorelines cover too much of the current shoreline, especially with many buildings less than 50' from the ordinary high water mark. A buffer area of native plants should be restored around the lake, especially on those sites that now have traditional lawns mowed to the water's edge or buildings very close to the water's edge. Stormwater management of these disturbed or impervious surfaces is essential to maintain the high quality of the lake water.

(3) No lawn chemicals should be used on properties around the lake. If they must be used, they should be used no closer than 50' to the shore. Irrigation with lake water, which contains many nutrients, should be all the fertilizer that would be needed.

(4) An aquatic plant management plan should be developed with a regular schedule of machine harvesting. Such plans will be required by the Wisconsin DNR for aquatic plant permits and grants and will also assist in reducing the frequency and density of the invasive plants in Goose Lake.

(5) The plan should include target harvesting for Eurasian Watermilfoil (EWM).

(6) The Goose Lake Association may want to apply for grants from the Wisconsin Department of Natural Resources to help defray the cost of EWM management.

(7) No broad-scale chemical treatments of aquatic plant growth are recommended due to the undesirable side-effects of such treatments, including increased nutrients from decaying plant material and decreased dissolved oxygen and opening up more areas to the invasion of EWM.

(8) Fallen trees should be left at the shoreline.

(9) Although Adams County Land & Water Conservatism Department currently takes regular surface water samples, the program only goes through 2006. Goose Lake residents should continue to be involved in the Wisconsin Self-Help Monitoring Program to permit on-going monitoring of the lake trends for basically no cost.

(10) Goose Lake residents should identify, cooperate with and participate in watershed programs that will reduce nutrient and sediment inputs.

(11) Sensitive vegetation, emergent vegetation and lily pad beds should be protected where they are currently present. These not only provide habitat, but also help stabilize the shores.

(12) The areas where there is undisturbed wooded shore should be maintained and left undisturbed.

(13) Designated sensitive areas should be maintained and left undisturbed. Recommendations of sensitive area reports should be followed.

(14) The Goose Lake Association should develop and implement a lake management plan that takes into account all inputs from both the surface and ground watersheds and addresses the concerns of this lake community.

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